INTRODUCTION TO FLUIDS

PROPERTIES

Properties

Mass Density

The mass per unit volume of a substance, usually denoted as ρ. Typical values are:

- Water: 1000 kg/m^3;
- Mercury: 13546 kg/m^3;
- Air: 1.23 kg/m^3;
- Paraffin: 800 kg/m^3.

Specific Weight

The weight of a unit volume of a substance, usually denoted as γ. Essentially density times the acceleration due to gravity:

$$\gamma = \rho g$$

Properties

Relative Density (Specific Gravity)

A dimensionless measure of the density of a substance with reference to the density of some standard substance, usually water at 4°C:

$$\text{relative density} = \frac{\text{density of substance}}{\text{density of water}}$$

$$= \frac{\text{specific weight of substance}}{\text{specific weight of water}}$$

$$= \frac{\rho_s}{\rho_w} = \frac{\gamma_s}{\gamma_w}$$

Properties

Bulk Modulus

In analogy with solids, the bulk modulus is the modulus of elasticity for a fluid. It is the ratio of the change in unit pressure to the corresponding volume per unit volume, expressed as:

$$\frac{\text{Change in Volume}}{\text{Original Volume}} = \frac{\text{Chnage in pressure}}{\text{Bulk Modulus}}$$

$$\frac{-dV}{V} = \frac{dp}{K}$$

$$K = -V\frac{dp}{dV}$$

Properties

Bulk Modulus

In which the negative sign indicates that the volume reduces as the pressure increases. The bulk modulus changes with the pressure and density of the fluid, but for liquids can be considered constant for normal usage. Typical values are:

- Water: $2.05\ \mathrm{GN/m^3}$;
- Oil: $1.62\ \mathrm{GN/m^3}$.

The units are the same as those of stress or pressure.

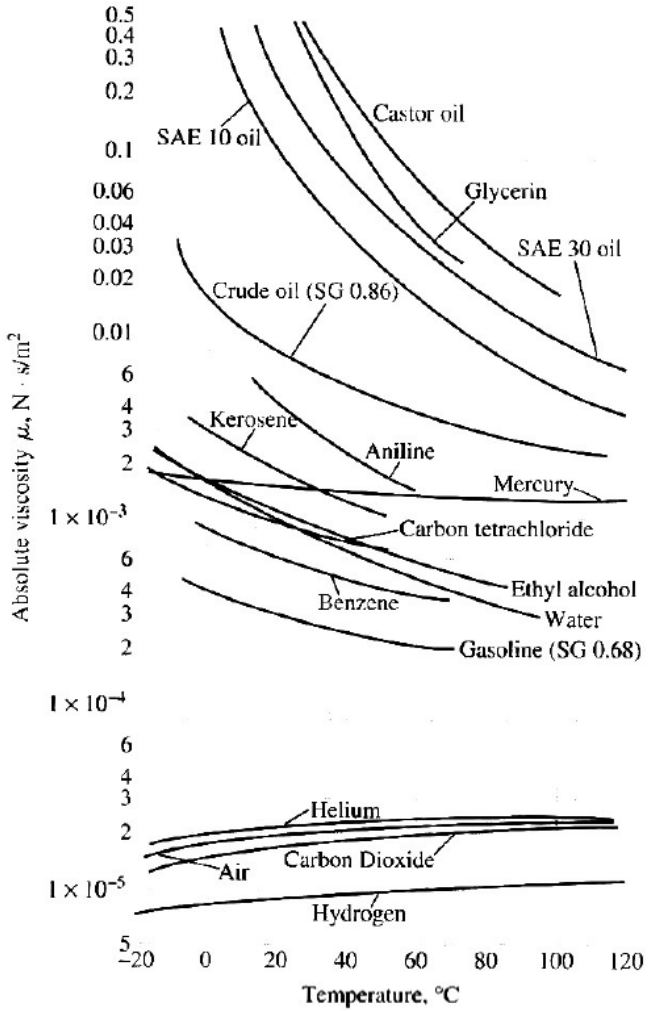
Properties

Viscosity

The viscosity of a fluid determines the amount of resistance to shear force. Viscosities of liquids decreases as temperature increases and are usually not affected by pressure changes. From Newton's Law of Viscosity:

$$\mu = \frac{\tau}{du/dy} = \frac{\text{shear stress}}{\text{rate of shear strain}}$$

Hence the units of viscosity are Pa.s or $N.s/m^2$. This measure of viscosity is known as dynamic viscosity and some typical values are given:



Properties

Specific Volume

The volume occupied by a unit mass of fluid.

$$V_s = \frac{1}{\rho}$$

Kinematic Viscosity

The ratio of the dynamic viscosity of the fluid to its mass density.

$$v = \frac{\mu}{\rho}$$

Surface Tension (Capillarity)

Compressibility

Properties

Property Changes in Ideal Gas

For any ideal gas experiencing any process, the equation of state is given by:

$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$$

When temperature is held constant (*Boyle's Law*):

$$p_1 V_1 = p_2 V_2$$

When pressure remains constant (*Charle's Law*):

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

For adiabatic or isentropic conditions (*no heat exchanged*):

$$p_1 V_1^k = p_2 V_2^k$$

Properties

Problem Set 1

Problem 1

If 6 m^3 of oil weighs 47 kN, find its specific weight, density, and relative density.

Ans: y = 7.833 kN/m^3, ρ = 798 kg/m^3, s = 0.800

Properties

Problem Set 1

Problem 2

A reservoir of carbon tetrachloride has a mass of 500 kg and volume of 0.315 m^3. Find the carbon tetrachloride's weight, mass density, specific weight, and specific gravity.

Ans: W = 4.905 kN, ρ = 1587 kg/m^3, y = 15.57 kN/m^3, s = 1.590

Properties

Problem Set 1

Problem 3

Air is kept at a pressure of 200 kPa absolute and a temperature of 30^0C in a 500-liter container. What is the specific weight and mass of air?

Ans: y = 0.023 kN/m^3, M = 1.15 kg

Properties

Problem Set 1

Problem 4

A liquid compressed in a cylinder has a volume of 1000 cm^3 at 1 MN/m^2 and a volume of 995 cm^3 at 2 MN/m^2. What is its bulk modulus of elasticity?

Ans: E_b = 200 MPa